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STUDYING THE PHASE COMPOSITION OF METEORITIC IRON BY THE LOCAL X-RAY SPECTRAL ANALYSIS METHOD

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STUDYING THE PHASE COMPOSITION OF METEORITIC IRON BY THE LOCAL X-RAY SPECTRAL ANALYSIS METHOD

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ABSTRACT

The article discusses investigation of the place composition of meteoritic iron to determine origin. Chemical composition, lattice parameters and phase microhardness are discussed, and heterogeneities are considered. The 1938 Chebankol meteorite is analyzed and Widmanstätten structure included.

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Investigations of iron meteorites performed over a period of many years have shown that their substance consists of a solic solution of iron, nickel (from 4 to 60 percent) and cobalt (from 0.3 to 0.7 percent) with inclusions of iron sulfide FeS and primary and secondary crystals of iron-nickel phosphide $(Fe, Ni,)_3P$. Iron meteorites containing approximately 6 percent nickel consist of one α-phase; most of the meteorites contain over 6 percent Ni and consist of a mixture of α- and γ-phases. Finally, individual meteorites which contain approximately 60 percent nickel consist of one γ-phase. Most twophase meteorites consist of the so-called octahedrites, with a coarsely /256*

*Numbers given in the margin indicate the pagination in the original foreign text.

crystalline Widmanstätten structure while the lesser part, called ataxites consists of a sufficiently homogeneous, finely divided mixture of α- and γ-phases. In octahedrites the α-phase (the so-called kamacite) has the form of beams of various width situated along the planes of the octahedrite edged with thin planes of the γ-phase (the so-called tenite). Study of the composition of individual phases of meteoritic iron plays an important role in the question of the origin of meteorites. These investigations make it possible to clarify the degree of phase equilibrium and the phenomenon of diffusion which characterize the conditions under which iron meteorites were formed.

Few works are known which determine the chemical composition (ref. 1), the lattice parameters (ref. 2), and the microhardness (ref. 3) of the individual phases of iron meteorites. The data (ref. 1) refer to the average phase composition. However, substantial variations in microhardness of the γ-phase within the same meteorite indicate that its composition is heterogeneous. Recent investigations of the phase composition of several octahedrites (ref. 4) have yielded different results.

Table 1 gives a brief summary of the results obtained in references 1 and 4.

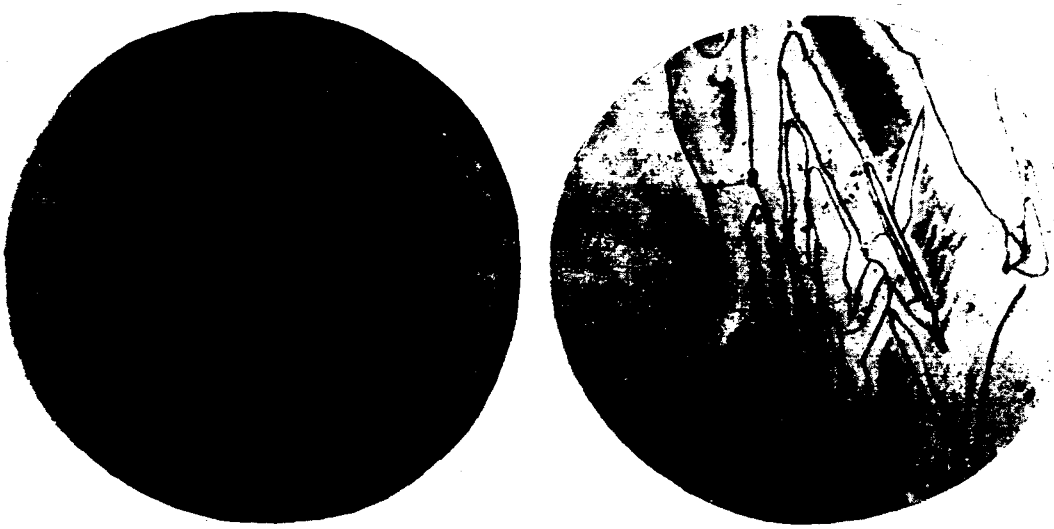
In reference 4 the γ-phase was isolated by etching and an effort was made to determine the heterogeneiety of its composition across the band. However, results obtained indicate that there is a decrease in nickel content in the

TABLE 1.

Element	α-phase		γ-phase	
	(ref. 1)	(ref. 4)	(ref. 1)	(ref. 4)
NI, percent weight	52.6-6.81	3.3-5.8	13-48	31-54
Co, percent weight	0.25-0.83	0.43-0.61	0.02-2.1	0.04-0.15

direction toward the boundary of the γ-phase. There are some doubts concerning these results due to the inadequate method of isolating phases. At the same time it is precisely such data as the phase composition at the boundary between them and the nature in the variation of the concentration of individual elements as a function of distance from this boundary that are of particular value in solving this problem.

To investigate the phase composition, we selected the recently /257 developed X-ray spectral analysis of microvolumes (ref. 5). The object of the investigation was the Chebankol iron meteorite (discovered in 1938) which, according to the analysis of M. I. D'yakonova, contained 9.03 percent Ni and 0.44 percent Co. It has a clearly defined Widmanstätten structure and belongs to a type of coarse-structure octahedrite (fig. 1). We investigated the continuous distribution of iron, nickel and cobalt with the recording of concentration



a b

Figure 1. Structure of different regions of Chebankol iron-nickel meteorite. a, region with wide bands and the γ-phase; b, region of fine-grain plessite. (210 X).

curves when moving across the α-phase beams and the γ-phase bands. The composition of phases forming the Widmanstätten structure has been established and in the case of the finely dispersed mixture of phases the average composition was determined.

The typical result of the first series of measurements is shown in figure 2. Here we first see clearly the boundary between the phases as a discontinuity in the content of all basic alloy components. Furthermore, in all the measurements we can see clearly the increase in nickel content and a decrease in iron and cobalt from the center of the γ-phase band toward its edge with the extreme value at the very boundary of the phase.

The presence of a sharp boundary between the phases and the form of the concentration curves in the γ-phase show that this meteorite was not subjected to heat after crystalization. Such heat could have produced a variation in the composition and ratio of phases in the region of the lower transition temperature $\gamma \rightarrow (\gamma + \alpha)$ or the diffusion of nickel and cobalt at a temperature above this transition.

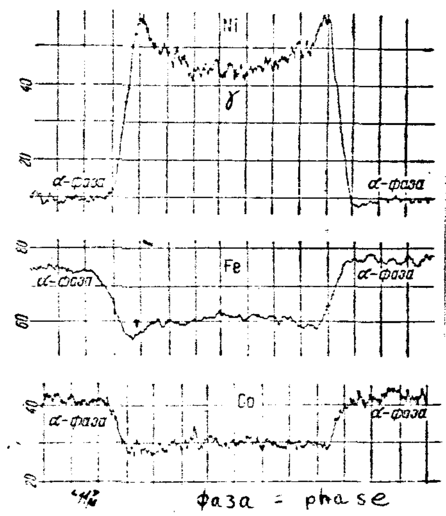


Figure 2. Distribution of nickel, iron and cobalt in the γ-phase.

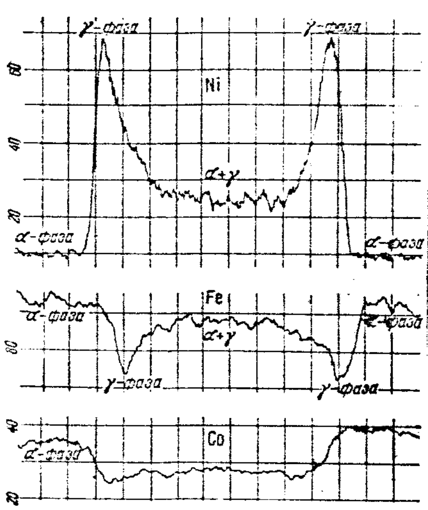
It is important to consider the question of the equilibrium of the phase composition in iron meteorites. It is obvious that at certain temperatures and pressures the equilibrium composition of the alloy would be associated with a phase composition at the boundary between them even in the case when the entire system had not yet attained the equilibrium state completely.

As we can see from figure 2, both phases of meteoritic iron, in spite of its extremely slow cooling (which is indicated by the rather coarse crystalline structure of iron meteorites), is heterogeneous in its composition, i.e., this system is not completely in equilibrium. The nickel content in the α-phase decreases from 7.6 percent in the basic mass to 6.4 percent in the narrow layer at the very boundary with the γ-phase. At the same time, in the γ-phase nickel concentration increases from 32 percent at the band center to 42 percent at its boundary. Therefore the equilibrium nickel content in this meteorite would be 6.4 percent Ni for the α-phase and 42 percent for the γ-phase. These quantities were repeated in different parts of the meteorite. Equilibrium content of cobalt in the α-phase is 0.60 percent while in the γ-phase it is 0.30 percent, i.e., the cobalt concentration in the γ-phase is lower than in the α-phase.

A comparison of the data on the nickel with the structural diagram of the Fe-Li system constructed under conventional conditions (with a normal pressure) (ref. 6) has shown that the results which have been obtained correspond to temperatures which differ by approximately 20°. It is possible that this disagreement can be explained to some extent either by the increased /258 pressure during the crystallization of the meteorite or by the displacement of the surfaces of the structural diagram of the triternary system for the alloy containing approximately 0.5 percent Co.

On the other hand, data on the nature of variation in the concentration of nickel may indicate that there is a decrease in the limit of solubility for nickel in the α-phase with cooling, beginning with some temperature, i.e., the transition line $\alpha \rightarrow \alpha + \gamma$ in the region of lower temperatures must have a bend in the direction of lesser concentrations of nickel. Such a bend was noted earlier on the structural diagram of the Fe-Ni system (ref. 7) and was also obtained from thermodynamic considerations (ref. 8).

Measurements of the phase composition in the regions of the plessite where the γ-phase bands are divided by narrow strips of the α-phase, showed a similar picture for the distribution of elements. Inside the individual γ-phase bands, regions of the fine grain mixture of $\gamma+\alpha$ phases were also noted. The distribution of nickel, iron and cobalt in such a band is shown in figure 3. As we can see the nickel content in such a fine grain plessite is constant and constitutes 20 percent. A higher concentration of nickel compared to its average content in the meteorite may indicate that such a structure was formed during a later transformation



фаза = phase

Figure 3. Distribution of nickel, iron and cobalt in the γ-phase including finely dispersed $\alpha + \gamma$ mixture.

of the γ-phase (at somewhat lower temperatures). This result is also in agreement with the form of the structure which indicates the initial stage of phase separation. Data obtained confirm the point of view of some investigators concerning the late formation of plessite of this type and present a certain concept on the kinetics of transformation in the iron-nickel alloys.

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